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Guidelines for Minimizing Spruce Beetle Populations in Logging Residuals

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Abstract

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Different categories of logging residuals were evaluated from the standpoint of attack density and brood production. The bottom surfaces of cull logs and tops generally had higher attack and brood densities than the upper surfaces. Stumps had considerable variation in attacks and brood between the north and south side. General guidelines for minimizing beetle production from logging residuals are developed from the results.

Keywords: *Dendroctonus rufipennis, Picea engelmannii* Parry, spruce beetle control.

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Guidelines for Minimizing Spruce Beetle Populations in Logging Residuals

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Contents

Guidelines for Minimizing Spruce Beetle Populations in Logging Residuals

J. M. Schmid

Beetle Management Guidelines

Several precautions can be taken to reduce the possibility of spruce beetle buildup in logging residuals. Trees should be cut as low to the ground as possible to reduce stump height, preferably less than 1.5 ft. Cull logs and tops should be limbed and the branches kept away from the bark surface of the bole. After limbing, the cull logs and tops should not be piled but positioned away from any shade. Their directional orientation is not important. Logs and tops should be cut into short lengths, the shorter the better. Naturally, complete removal or destruction of all cull logs and tops would eliminate the most significant host material. If trees are logged full length, then the diameter of the small end should be 3 to 4 in.

Except for complete elimination of host material, even the previous recommendations will not prohibit beetles from inhabiting the bottom surfaces of logs and tops. If subsequent evaluation shows beetle populations in these surfaces to be high, they should then be treated by solar heat, with chemicals, or burned.

Where a substantial spruce beetle population exists in the adjacent forest, it may be wiser to leave the logging residuals rather than remove or destroy them immediately after cutting. Since the beetles will seek host material as they emerge, suitable residuals will attract beetles and reduce mortality of standing trees. After infestation, the residuals must be removed or treated.

These guidelines are applicable under selective, shelterwood, or clearcut silvicultural systems. The selective system obviously offers more shade for the residuals than does a clearcut. Under a selective system, prompt removal may be the best guideline.

Background

The spruce beetle, *Dendroctonus rufipennis* (Kirby), kills mature Engelmann spruce in the spruce-fir, *Picea engelmannii* Parry and *Abies lasiocarpa* (Hooker) Nutt., type in the Central Rockies. Since the late 1800's, populations of this bark beetle have periodically reached outbreak proportions and killed thousands of spruce. The known documented outbreaks have originated from windthrown trees, or residuals from cutting operations (Wygant and Lejeune 1967)—habitat extremely conducive for brood development. While most have developed from windthrow, occasional outbreaks have developed from logging residuals (McCambridge and Knight 1972)—the cull logs, tops and stumps of trees that remain after logging. Infestations in uncut stands adjacent to logging areas have been caused by beetles that developed in logging residuals.

Logging residuals have increased with the increase in timber harvesting in the spruce-fir type. This fact, coupled with the incidence of spruce beetles found in these areas, has concerned forest managers. Many remember the catastrophic White River outbreak in Colorado and, even though it didn't develop from logging residuals, foresee similar but less devastating outbreaks developing from residuals. Since little information on populations in logging residuals was available, a study was undertaken to evaluate beetle numbers in cull logs, tops and stumps.

Study Sites and Methods

Areas for study were selected on Apache Creek, Carson National Forest, New Mexico, and four sites in Colorado; Greenhorn Mountain Road, San Isabel National Forest; Taylor Mesa, San Juan National Forest; and two near Cameron Pass, Colorado State Forest. The logged areas were generally clearcut and less than 10 acres. In each area at least 50% of the cull logs were infested with spruce beetles.

North-south transect lines were run across each logging area. Adjacent transects were one or two chains apart depending on the size of the area; since most areas were less than 5 acres, the distance was usually one chain. The N-S transects were started on the southern boundary of the logging area on the west side. Plot centers were established at 1- to 2-chain intervals along each transect.

Four categories of logging residuals (fig. 1) were sampled: (1) logs 8 ft or less in length, (2) logs 8 ft or more in length, (3) tops, and (4) stumps. When each

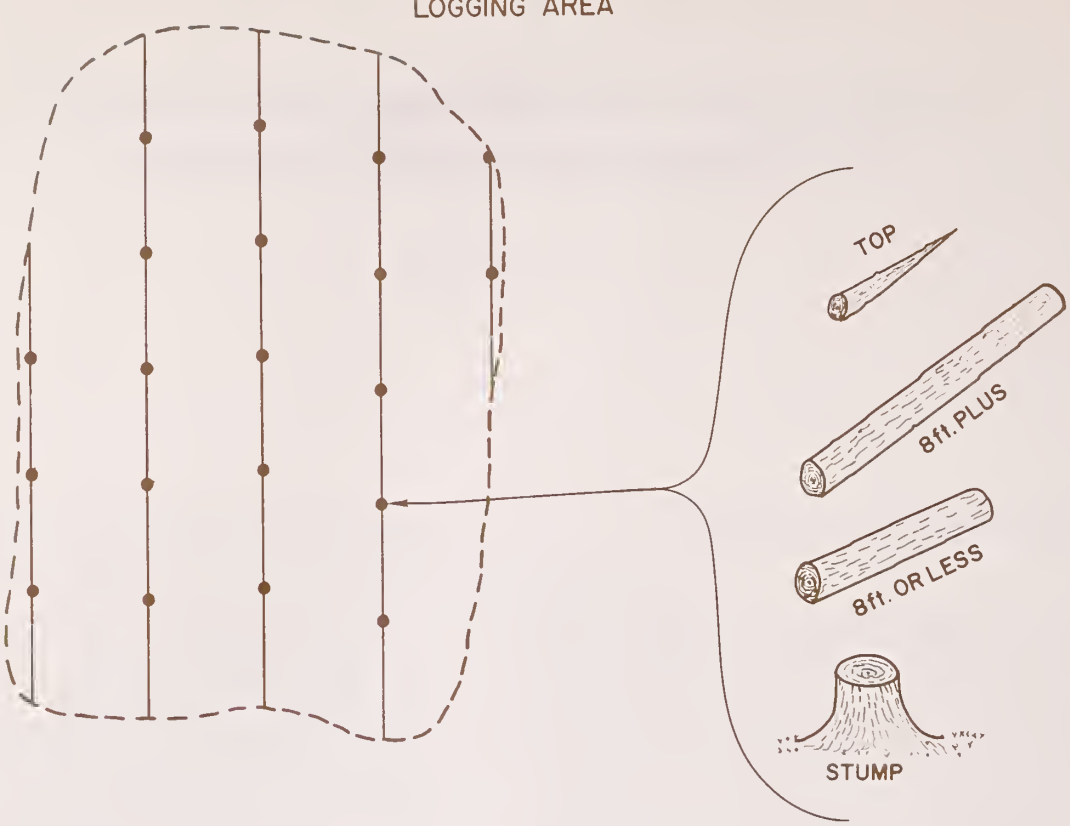

Figure 1.—Diagrammatic sketch of the 4 categories of logging residuals sampled at each plot center.

plot center was established on the transect line, the nearest residuals in each category was sampled (table 1).

Table 1.—Average size characteristics of logging residuals on the study areas

Residual category	Apache Creek	San Isabel	Taylor Mesa	Cameron Pass '68	Cameron Pass '69
	Logging area				
Stumps (*in*)					
Height	12.6	7.7	14.4	17.7	15.0
Diameter	17.8	23.5	25.8	26.9	20.8
Tops (*in*)					
Diameter at cut		8.0	8.3	7.9	7.5
Logs ($\leq$ *8 ft*)					
Length		5.9	5.2	5.3	5.3
Diameter (*in*) midway		15.9	20.3	23.6	15.6
Logs ($\geq$*8 ft*)					
Length	29.6	15.8	21.0	17.5	20.0
Diameter (*in*)					
large end	13.0	16.2	22.0	15.4	17.3
small end	8.4	12.9	16.6	12.8	14.8

A number of sampling points were established on each individual log and top, but the number varied with the log category and the infested portion of each unit. The initial sampling point on the 8 ft or more logs and on tops was 1 ft from the end of greater diameter. Additional sampling points were 5 ft or multiples of 5 ft from the initial sampling point. Samples were taken throughout the length of each log or top, or to the end of the infested portion; no minimum diameters were set. Logs less than 8 ft were sampled at one point at least 1 ft from either end.

A bark sample, 6 in by 6 in, was removed from each of four surfaces (top, two sides and

Cull log with bark samples removed.

bottom) on the circumference of the logs at each sampling point. Identically sized samples were removed from the upper and lower surfaces of the top at each sampling point, and from the north and south sides of stumps. If stump height was 3 ft or more on one or both sides, upper and lower samples were taken on the longer side. The upper samples were taken just below the cut and the lower samples slightly above ground level. Attacks, length of egg galleries, number of beetles, and diameter at the sampling point were recorded for each bark sample. Samples were taken so that there was no torn bark, woodpeckering, or branches in the sample.

In the Apache Creek area, beetles were only found in the logs exceeding 8 ft. In the San Isabel area, logs less than 8 ft had been turned by forest staff and did not represent the true situation.

Means of the attack and brood data were analyzed for significant differences within and between surfaces of a particular logging residual, between units of the four different categories, and between transect lines with unpaired "t" tests. Differences were tested for significance at the .05 level.

Results and Discussion

Attack Densities

Mean attack densities in the logs exceeding 8 ft were generally highest (1-8 per ft^2) on the bottom surface and lowest (< 1) on the top surface in all areas (table 2). On the lateral surface, densities (1-4) were generally intermediate between densities on the top and bottom surfaces.

Mean attack densities in logs less than 8 ft in length had different patterns between surfaces in the different areas (table 3). Densities in the Taylor Mesa area were highest (3-6) on the bottom, intermediate (1-3) on the lateral surface, and almost zero on top. Residuals in the two areas from Cameron Pass had greater densities on the bottom surface than on the top, but the bottom and lateral surfaces were not significantly different.

In tops, mean attack densities were significantly higher on the bottom surface (2-3) than on the top surface (≤ 1) in all areas (table 4). Beetles attacked tops down to a diameter of 3 to 4 in.

Table 2.—Mean number of attacks and live brood per ft^2 of bark in logs exceeding 8 ft in length

Logging area and sampling date	Number of samples			Attacks			Brood		
	Top	Lateral	Bottom	Top	Lateral	Bottom	Top	Lateral	Bottom
Apache Creek									
June 21-23, 1968	72	133	70	0.3 ± 0.2	0.5 ± 0.2	1.4 ± 0.4	2.5 ± 1.0	6.4 ± 1.4	18.8 ± 3.3
August 15-16, 1968	73	141	71	0.2 ± 0.1	0.3 ± 0.1	0.5 ± 0.2	0.3 ± 0.2	3.2 ± 1.1	7.7 ± 2.1
San Isabel									
July 22-24, 1968	53	104	53	0.5 ± 0.2	1.0 ± 0.1	1.2 ± 0.3	11.2 ± 3.9	32.4 ± 7.8	38.6 ± 9.6
Sept.11-13, 1968	53	105	52	0.5 ± 0.2	0.7 ± 0.2	1.0 ± 0.4	1.4 ± 0.7	11.0 ± 2.3	23.6 ± 5.5
Taylor Mesa									
August 17-21, 1968	77	153	77	0.7 ± 0.3	2.7 ± 0.4	8.7 ± 0.7	32.6 ± 15.3	117.8 ± 16.8	304.9 ± 25.3
July 14-17, 1969	74	148	74	0.8 ± 0.4	2.7 ± 0.4	6.8 ± 0.7	1.4 ± 0.8	25.2 ± 3.7	91.4 ± 8.4
August 16-17, 1969	77	154	77	0.3 ± 0.1	1.2 ± 0.1	3.4 ± 0.5	0	16.1 ± 2.8	75.4 ± 7.1
Cameron Pass									
July 2-11, 1968	74	144	74	0.5 ± 0.2	2.1 ± 0.3	3.0 ± 0.4	16.0 ± 5.6	40.7 ± 6.7	80.7 ± 9.9
August 27-30, 1968	74	144	74	0.5 ± 0.2	2.3 ± 0.3	3.6 ± 0.5	1.0 ± 0.6	14.0 ± 2.0	60.4 ± 7.0
Cameron Pass									
Sept.14, 1968	18	36	18	1.6 ± 0.8	4.4 ± 0.7	4.0 ± 0.9	53.6 ± 19.7	106.0 ± 16.6	148.0 ± 27.4
July 1-3, 1969	45	92	45	0.7 ± 0.2	3.6 ± 0.4	4.5 ± 0.6	7.7 ± 3.6	44.0 ± 4.2	70.2 ± 7.4
August 25-27, 1969	45	90	45	0.5 ± 0.3	3.0 ± 0.4	3.8 ± 0.6	1.1 ± 1.0	17.6 ± 2.5	51.7 ± 7.3

Table 3.—Mean number of attacks and live brood per ft^2 of bark in logs less than 8 ft in length

Logging area and sampling date	Number of samples			Attacks			Brood		
	Top	Lateral	Bottom	Top	Lateral	Bottom	Top	Lateral	Bottom
Taylor Mesa									
August 17-21, 1968	12	24	12	0	2.8 ± 0.9	6.0 ± 1.9	0	80.0 ± 27.0	179.0 ± 54.0
July 14-17, 1969	12	24	12	0.7 ± 0.7	1.7 ± 0.7	3.0 ± 1.7	0	18.7 ± 8.4	71.0 ± 25.7
August 16-17, 1969	12	24	12	0.3 ± 0.3	1.7 ± 0.8	2.2 ± 1.0	0	5.3 ± 2.8	51.0 ± 19.0
Cameron Pass									
July 2-11, 1968	14	28	14	2.0 ± 1.0	3.2 ± 0.7	2.6 ± 1.4	26.6 ± 16.3	51.8 ± 12.1	32.6 ± 12.6
August 27-30, 1968	14	28	14	2.3 ± 1.4	2.8 ± 0.6	2.0 ± 1.2	10.6 ± 8.9	44.6 ± 16.9	24.6 ± 8.1
Cameron Pass									
Sept. 14, 1968	4	8	4	1.0 ± 1.0	5.0 ± 1.5	5.0 ± 1.9	27.0 ± 23.2	109.0 ± 34.0	145.0 ± 42.9
July 1-3, 1969	12	23	12	0	3.7 ± 0.8	2.3 ± 1.2	4.3 ± 4.3	41.5 ± 9.5	41.0 ± 12.0
August 25-27, 1969	12	23	12	0.3 ± 0.3	2.2 ± 0.7	0.7 ± 0.4	3.3 ± 3.3	30.3 ± 9.0	27.3 ± 13.8

Table 4.—Mean number of attacks and live brood per ft^2 of bark in tops

Logging area and sampling date	Number of samples		Attacks		Brood	
	Top	Bottom	Top	Bottom	Top	Bottom
San Isabel						
July 22-24, 1968	67	67	0.4 ± 0.2	1.0 ± 0.2	4.8 ± 3.2	59.2 ± 10.4
Sept. 11-13, 1968	67	68	>0.1	1.2 ± 0.3	1.6 ± 1.2	46.4 ± 8.0
Taylor Mesa						
August 17-21, 1968	57	55	0.1 ± 0.1	3.1 ± 0.5	10.4 ± 3.2	164.8 ± 28.0
July 14-17, 1969	56	56	0	2.1 ± 0.4	0	54.0 ± 9.6
August 16-17, 1969	56	56	0.2 ± 0.1	1.8 ± 0.4	0	30.0 ± 5.6
Cameron Pass						
July 2-11, 1968	56	55	0.6 ± 0.3	3.4 ± 0.6	9.6 ± 4.0	91.2 ± 8.0
August 27-30, 1968	55	54	0.2 ± 0.1	3.0 ± 0.4	3.6 ± 1.6	24.4 ± 10.8
Cameron Pass						
Sept. 14, 1968	16	16	1.2 ± 0.1	2.8 ± 0.8	26.4 ± 24.0	102.8 ± 40.8
July 1-3, 1969	42	42	0.3 ± 0.2	2.8 ± 0.6	4.0 ± 3.2	43.2 ± 8.0
August 25-27, 1969	42	42	0.2 ± 0.2	1.8 ± 0.4	0	24.4 ± 4.8

Attacks in stumps varied between the north and south sides, top and bottom samples, and between study areas (table 5). The south sides had significantly higher densities in the San Isabel area while the north sides were higher in one area at Cameron Pass. The top and bottom north samples in the second area at Cameron Pass were different, but in most areas these samples generally differed by only one attack. Attack densities were not consistently different between the top and bottom samples as they were in Dyer and Taylor's (1971) study.

Attack densities were generally uniform along any of the three surfaces on the logs exceeding 8 ft, except for the ends and shaded top surfaces. This generally agrees with McComb (1953) who found a uniform density of attacks throughout the boles of trap trees except for low counts in the initial portion above the cut.

The top surface of exposed material was attacked only where it was shaded by branches from the limbing operation or crisscrossed logs. These shaded surfaces sustained attack densities comparable to those on the lateral or bottom surfaces.

Removing bark sample from stumps.

Table 5.—Mean number of attacks and live brood per ft^2 of bark in stumps (letters T and B in parentheses indicate top and bottom samples)

Logging area and sampling date	Number of samples North	Number of samples South	Attacks North	Attacks South	Brood North	Brood South
San Isabel						
July 22-24, 1968	19	19	0.2 ± 0.2	0.8 ± 0.5	14.3 ± 13.9	28.2 ± 21.4
Sept.11-13, 1968	19	19	0.2 ± 0.2	0.6 ± 0.5	3.6 ± 3.2	11.2 ± 9.0
Taylor Mesa						
August 17-21, 1968	32	30 (T)	4.2 ± 1.2	4.2 ± 0.9	203.6 ± 68.0	124.8 ± 29.5
		(B)	4.9 ± 2.0	5.4 ± 2.2	204.3 ± 85.0	126.6 ± 62.1
July 14-17, 1969	30	27 (T)	1.3 ± 0.7	1.3 ± 0.7	17.7 ± 6.8	13.3 ± 9.3
		(B)	2.6 ± 1.2	2.5 ± 2.5	19.6 ± 10.0	3.1 ± 2.6
August 16-17, 1969	32	22 (T)	1.8 ± 0.7	1.2 ± 0.6	26.7 ± 5.2	12.7 ± 4.8
		(B)	2.9 ± 1.1	2.0 ± 1.2	45.7 ± 15.7	0
Cameron Pass						
July 2-11, 1968	42	42 (T)	2.3 ± 0.6	2.8 ± 0.8	49.1 ± 12.3	44.6 ± 12.6
		(B)	3.3 ± 0.8	3.1 ± 1.6	65.6 ± 15.9	43.2 ± 15.3
August 27-30, 1968	35	34 (T)	2.6 ± 0.7	2.0 ± 0.7	18.2 ± 10.2	5.6 ± 2.5
		(B)	2.4 ± 0.8	1.4 ± 0.7	37.9 ± 16.6	20.0 ± 9.6
Cameron Pass						
Sept. 14, 1968	6	9 (T)	9.3 ± 3.5	3.2 ± 2.3	194.7 ± 82.5	140.8 ± 91.0
		(B)	5.3 ± 3.5	2.0 ± 1.2	80.0 ± 40.3	100.0 ± 62.4
July 1-3, 1969	14	24 (T)	3.6 ± 1.0	2.2 ± 0.7	39.6 ± 12.6	30.8 ± 9.5
		(B)	2.7 ± 1.3	1.8 ± 0.8	33.3 ± 16.4	39.0 ± 11.9
August 25-27, 1969	15	21 (T)	0.7 ± 0.5	1.5 ± 0.8	6.6 ± 3.3	7.4 ± 3.5
		(B)	3.0 ± 1.9	2.0 ± 0.8	15.0 ± 10.4	12.5 ± 10.8

Along the bottom surface, attacks were often less numerous within 1 to 2 ft of either end of the log than in intermediate samples. The phloem near the ends was drier and thus less suitable for attack.

Densities along the bottom were also affected by contact of the log with the ground, which, as McComb (1953) notes, prevents beetles from reaching the bark surface. Ground contact also increased the moisture content of the bark, which enhances fungus development. McComb (1953) and Nagel et al. (1957) noted that fungus-covered bark was free of beetle attacks.

Ground contact and moist bark also explained why the 8 ft or less logs in some areas had greater attack densities on the lateral surface than on the bottom; the shorter the log, the greater the possibility of it sinking into the ground and thereby excluding beetle attacks.

Ground conditions frequently affect attack densities. If the ground is unfrozen and wet when the log is felled, the log will usually sink into the ground and become unavailable along the bottom. Logs felled on frozen wet ground may sink in during the thawing season. Since beetle attack nearly coincides with the "spring runoff", logs in the path of running water may be unattractive to beetles.

Attack densities along the top surface of the logs in this study (0.3-1.6) were nearly identical to those (0.0-0.2) found by Dyer and Taylor (1971) in logging slash in British Columbia. Densities on the bottom surface (1.4-8.7) had a greater range than those of Dyer and Taylor (2.2-4.5). Neither study had attack densities quite as large as those found by Nagel et al. (1957), which were 1.9 and 12.7 on the top and bottom surfaces of exposed trap trees.

Attack densities can be misleading as indicators of population trend because of significant variation within the individual logging residual (stump, top or log), as well as between the residuals and between the same residuals in different transect lines. In stumps, 26% to 84% of those sampled in the five areas had no attacks. In tops, 8% to 47% were not attacked. In logs 8 ft or less, and 8 ft or longer, 0% to 63% and 0% to 17%, respectively, were not attacked.

The number of attacks is partially a function of logging procedures. Since beetles prefer shaded host material, piled logs will have a higher density of attacks than more exposed logs, regardless of their location in the cutting area. Exposed logs near the edge of a cutting area will have fewer attacks per ft^2 than logs covered by branches near the center of the area. This partially explains why certain transect lines had higher attack densities than others, and why some logs were unattacked.

The unattacked host material further clarifies the point raised by Lister et al. (1976), who suggested that attack densities were governed to a large degree by the existing beetle population and the amount of downed host material—in this case, logging residuals. When the resident beetle population is quite low, such as in Apache Creek, even a small logging area may have more cull material than can be thoroughly occupied by the beetles. The remainder becomes unsuitable before additional attack is possible the next year. Thus a large percentage of the residuals remains unattacked so that the mean densities are low. In the other extreme, when the resident beetle population is high, the host material is more densely attacked and mean densities are high. Carried to a logical conclusion, attack densities might approach those found by Nagel et al. (1957) on exposed trap trees. Of course, only the resident beetle population has been varied in this discussion. In reality, the amount of residual host material also varies, both in amount per acre and by the number of logged acres. Thus, mean attack densities must be viewed in relation to the conditions from which they were derived.

Between sampling periods, attack densities remained about the same. This suggests that there is no secondary infestation of the host material by another generation of adults. In general, logging residuals are either infested by beetles the first time they are available during an attack period or they become unsuitable by the next attack period a year later. The attack densities obtained during the summer of attack are the best estimates.

Brood

Beetle numbers in logs exceeding 8 ft were highest (19-305 per ft^2) along the bottom surface, intermediate (6-118) on the lateral surface, and lower (2-54) along the top (table 2). Numbers were significantly different between surfaces in each area. The brood was generally uniform within the lateral or bottom surfaces except near the ends ~~of~~ where much of the bark on the bottom touched the ground. This uniformity in brood and density of attacks along the lateral and bottom samples indicates that a single sample anywhere along these surfaces will reflect the density therein.

Beetle numbers in logs less than 8 ft generally followed the same pattern as the densities in the longer logs except that the numbers on the lateral surfaces were equal to, or higher than the numbers on the bottom in two areas (table 3). Numbers were significantly different between surfaces during the first sampling period in Cameron Pass, but became insignificant in succeeding sampling periods.

The bottom surface of tops had significantly higher beetle densities (60-165) than the upper surface (5-26) during the first sampling periods for each area, and this difference remained unchanged in later samplings (table 4).

Brood Mortality

Brood mortality in the top surface of tops and cull logs approached 100% by the end of the second summer, except where branches or logs covered the surface. This mortality is primarily attributable to high bark temperatures (Mitchell and Schmid 1973). High temperatures also dry the phloem, which becomes less suitable for larval development.

Mortality in the lateral and bottom surfaces of cull logs and the bottom surface of tops generally exceeded 50% between the summer of attack and the next summer; in some bottom surfaces, mortality exceeded 75% (table 6). Mortality during the latter summer varied by brood density. Where densities were relatively low (Apache Creek and San Isabel), densities decreased more than 50% in the second summer. Where densities were relatively high (Taylor Mesa and Cameron Pass), they decreased 25% or less (table 6). This mortality was due to physical and biotic factors.

Table 6.—Percent mortality of the broods between sampling periods, by area

Logging residual	Logging area						
	Apache Creek	San Isabel	Taylor Mesa		Cameron Pass '68	Cameron Pass '69	
Stumps							
Top, north	65	[1]75	91	[2]87	63	80	[2]97
Bottom, north			90	78	42	58	81
Top, south		[1]60	89	90	87	78	95
Bottom, south			98	100	54	61	87
Tops							
Top		69	100	100	63	84	100
Bottom		21	67	82	35	58	76
Logs, ≤ 8 ft							
Top		[3]0	[3]0	[3]0	60	44	88
Lateral		45	60	72	14	72	81
Bottom		61	77	93	25	62	72
Logs ≥ 8 ft							
Top	88	87	96	100	94	86	98
Lateral	51	66	70	75	66	50	63
Bottom	59	39	79	86	25	58	84

[1]Stumps lacked enough height to be subdivided into top and bottom samples.

[2]This column indicates mortality between first and third sampling periods; all other columns indicate mortality between first and second sampling periods.

[3]Estimates indicated no change or higher densities during the subsequent sampling period.

Brood mortality in stumps generally approached 90% between sampling periods in consecutive years. Mortality averaged about 65% during the second summer of development. Dehydration of the phloem caused much mortality because, as the phloem near the the cut surface dried, it separated from the wood and exposed the brood. Bark separation also allowed water to run between the phloem and the xylem, temporarily causing the phloem to become too moist and unsuitable for larval development. The bark on stumps was more frequently scraped than on other categories of logging residuals, and this also caused mortality.

Beetle Production by Residual Category

Beetle production was generally highest in logs exceeding 8 ft (table 7) because of their greater bark surface area (dependent on the log's diameter and length). Logs less than 8 ft usually produced more beetles than tops except when they were unusually short or small diametered. Stumps accounted for the smallest percentage of beetles because of their limited bark surface and high brood mortality.

Table 7.—Number and percent of spruce beetles associated with the average logging residual unit [1]

Logging residual	Apache Creek		San Isabel		Taylor Mesa		Cameron Pass '68		Cameron Pass '69	
	No.	%	No.	%	No.	%	No.	%	No.	%
Stumps	[2]0	[2]0	29	2	177	4	212	7	71	3
Tops	[2]—	[2]—	730	43	432	10	470	15	296	10
Logs ≤8 ft	[2]—	[2]—	215	13	522	12	870	27	443	16
Logs ≥8 ft	302	100	717	42	3,212	74	1,623	51	1,962	71

[1]Numbers calculated from mean brood densities at time of last sample and bark surface areas based on dimensions in table 1.

[2]Inadequate number sampled.

Each category of logging residuals was not always equally represented in every area. For every cut tree there was always a stump and top, but cull logs (both sizes) were less frequent. When the relative frequency of each category is considered in the production of beetles, the number and percent of produced beetles changes drastically for some categories (table 8).

Table 8.—Number and percent of spruce beetles associated with the weighted average logging residual unit. Percent may not add to 100 because of rounding

Logging residual	Apache Creek		San Isabel		Taylor Mesa		Cameron Pass '68		Cameron Pass '69	
	No.	%	No.	%	No.	%	No.	%	No.	%
Stumps	0	0	116	3	885	14	700	15	476	10
Tops	*	—	2,920	75	2,160	33	1,551	33	1,983	41
Logs ≤8 ft	302	100	717	18	3,212	49	1,623	34	1,962	40
Logs ≥8 ft	*	—	129	3	235	4	870	18	443	9

The importance of each category will depend on the stand conditions in each logging area. If the stand is relatively free from defect, cull logs may be nonexistent so that only tops and stumps would be present for beetle habitation and, therefore, the important residuals. Stands where the trees are either entirely cull or sound would not have logs less than 8 ft contributing to beetle production.

The contribution of the individual stump (table 7) appears negligible but, collectively, (table 8) stumps may contribute significantly. Stumps become more productive and thus more significant if stump height increases. Stump height averaged less than 1.5 ft in the different sample areas; this dimension would be a good criteria for minimizing beetle production. Even this height can be deceiving on steep sidehills, however. Since stump height was measured on the uphill side, stumps can have a downhill height of 3-5 ft at the same time their uphill height is less than 1.5 ft. Under these conditions, stumps may need treatment.

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Different categories of logging residuals were evaluated from the standpoint of attack density and brood production. The bottom surfaces of cull logs and tops generally had higher attack and brood densities than the upper surfaces. Stumps had considerable variation in attacks and brood between the north and south side. General guidelines for minimizing beetle production from logging residuals are developed from the results.

Keywords: *Dendroctonus rufipennis, Picea engelmannii* Parry, spruce beetle control.

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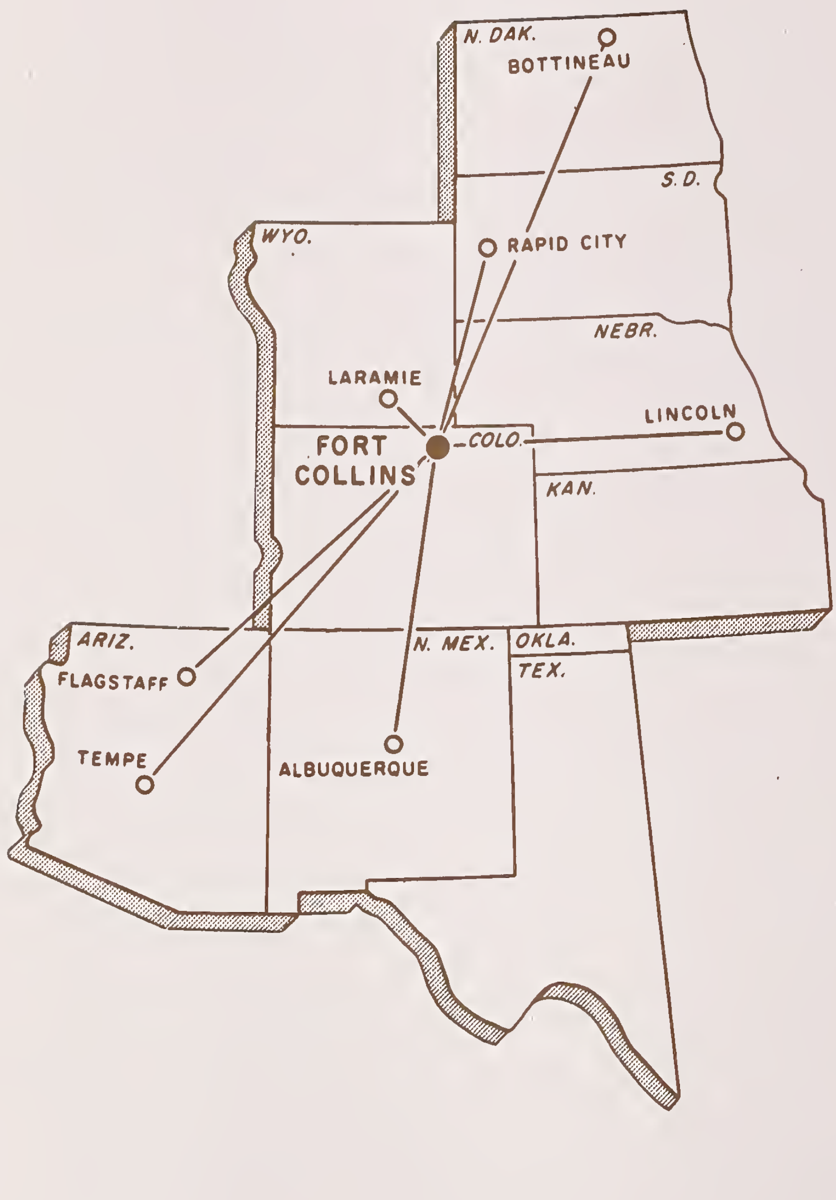
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